FRBSF Weekly Letter

Number 93-19, May 14, 1993

Computers and Productivity

It would be hard to imagine walking into almost any workplace—from a supermarket to a chemical plant to a travel agency—and not finding computers playing an important role. Therefore, it would seem safe to say that information technologies must be having a strong, positive impact on productivity. Indeed, research has found that computer users receive a significant premium in average wages relative to non-computer users, and this premium has been retained despite rapid growth in the number of computer-literate workers.

At the same time, however, some empirical work fails to find evidence that computer purchases increase productivity significantly. This *Letter* reviews these empirical studies briefly, and then discusses a possible solution to this puzzle: namely, the deviation between measured productivity effects and compensation patterns may be caused by errors in measuring output, so that analyses of productivity gains by computer users—and their industries—may be significantly underestimated.

Recent studies

Several studies have attempted to measure the effect of computer purchases on productivity. Morrison and Berndt (1991) looked at productivity gains attributed to investment in information technologies in U.S. manufacturing industries over the period 1952 to 1986. Their empirical work—which relies on estimates of output by industry—suggested that firms had over-invested in those technologies, and that the costs of the equipment exceeded their benefits.

Loveman (1990) found similar results using data for manufacturing firms in the U.S. and Western Europe. He found that investment in information technologies between 1978 and 1984 had "little, if any, marginal impact on output or labor productivity, while all other inputs into production—including [non-information technologies] capital—had significant positive impacts on output and labor productivity" (p.5).

This paradox—heavy investment in technologies that do not appear to have any benefit—has several potential explanations. First, the period covered in the data may be anomalous, and a longer period or more recent data might give different results. In fact, more recent unpublished work by Berndt and Morrison suggested that investments in the last several years may now be increasing productivity in manufacturing industries.

Second, organizational factors may have reduced the apparent payoff of informational technologies. Loveman argues that firms were making huge investments in these technologies at the same time that they were incurring large costs in "right-sizing" their operations to meet increased international competition. Thus, the returns to the technologies are difficult to isolate from the many changes in other factors of the firm's production technology. Moreover, firms may have engaged in poor ex ante capital budgeting, in large part because they lacked good understanding of the potential payoffs to those investments.

Several authors also have pointed out the implications of a learning curve for computer users. New information technologies must be assimilated into the system and workers must be trained to use them before any productivity gains can emerge. For example, while workers clearly can produce revised documents faster using a wordprocessor, the wordprocessing program takes time to learn. Thus, it could be that the large investments of the early 1980s did not bear fruit until the latter part of the decade, a time of rapid productivity growth in the manufacturing sector.

Measurement problems

Another explanation for the lack of measured productivity gains attributed to computer use is simply the output of computer-using industries is underestimated. As noted in a previous *Weekly Letter* (Schmidt, 2/14/92), the official output measurements generated by the U.S. Bureau of Economic Analysis (BEA) may be fraught with unavoidable conceptual and measurement problems.

Specifically, measuring the effect of information technologies on labor productivity of computer

users is quite difficult. Most of the studies have concentrated on manufacturing productivity, because it is thought that the outputs from those industries are better measured. However, adjustments in quality are difficult to embed in output measures, and it may be that quality is most affected by the use of increased computerization.

Consider the automobile industry. During the last two decades, this industry has changed dramatically, with domestic producers losing market share to foreign producers, particularly to Japan. One of the biggest factors underlying the loss of market share was the perception that Japanese cars were better-built than domestic cars. To combat this perception, U.S. auto manufacturers have spent billions of dollars on computersand robotics to reduce defects and increase precision.

Now consider how this investment in computers affects productivity measures. Productivity, as measured by the *number* of cars produced per worker, may not have been significantly increased by the investment. The most important impact of computerization is on quality and competitiveness (reducing product development time, responding to changing tastes and competition, and moving to lower-cost "just-in-time" inventory practices). These effects may not be captured in the BEA measures of output, although they do represent gains in the real output to the consumer—a better car.

Outside of manufacturing, the problem of measuring the effects of information technologies is even harder, and many of those industries are some of the heaviest users of information technologies. Problems estimating the output from service-producing industries are formidable. While some services can be counted objectively, often services embed a qualitative factor that cannot be directly recorded. The output received by a customer of a service often includes intangible factors resulting from the interpersonal relations involved in the transaction.

Moreover, in many of the service-producing industries, BEA has relied upon measures of inputs or input prices and assumptions about productivity to get measures of output. Thus, in some industries, such as banking, BEA counts changes in the number of employees and uses that as a proxy for output changes. Therefore, if these industries have invested heavily in computers over the last two decades, and have thereby saved on expanding their work force, then, by construction, BEA's measure will reveal little or no productivity gains to their investment in information technologies.

BEA's proxies for output and the implications for productivity effects from information technologies are problematic for other industries as well. For example, in the trucking industry, output is measured by the number of ton-miles traveled. Firms that have installed satellite communications and computerized delivery services now can reroute trucks while they are on the road. As a result, trucking firms can reduce their total distance traveled and deliver their product more efficiently. With BEA's methodology, however, this increase in efficiency is counted as a decrease in output, since mileage declines. Thus, measured productivity decreases in their calculation because of the efficiencies generated by the investment in information technologies, even though the firms are providing more and better services.

Computers and compensation

These conceptual explanations for underestimated productivity gains from computer use are consistent with some recent empirical evidence on compensation patterns. For example, Krueger (1993) looked at compensation to workers over the period 1984 to 1989, using a data set that asked about computer use at work and at home. His findings indicated that the salaries of computer users reflected a significant premium, roughly 10 to 15 percent more than comparable workers who did not use computers. Moreover, this premium persisted between 1985 and 1989. Krueger concluded that a large portion of the rising return to education could be explained by the increasing use of computers by those with more education.

This result directly challenges the proposition that computer use has not added to productivity. As industries have increasingly invested in computers, they have paid more to workers who use those machines. Moreover, given that the supply of computer-using individuals rose sharply during Krueger's study period, the persistence of the premium suggests that the higher wages reflected greater productivity of those individuals, rather than simply a shortage of those workers. (The existence of a differential at the time that firms were rapidly introducing computers into the workplace also suggests that some computer-related productivity gains were immediately

recognized by the firm, even if the firm faced a learning curve in taking full advantage of computerization.) If productivity did not increase as a result, it would be expected that those firms that invested in computers would fail, because of higher costs attributed to both the computers and the wages paid to the computer users.

Compensation patterns across industries provide further evidence of a schism between measured productivity gains and measured compensation gains—particularly in computer-using industries. As discussed in the earlier *Weekly Letter* (2/14/92), changes in average compensation provide an alternative proxy of labor productivity growth in a given industry. While most industries have invested heavily in computers, several service industries have shown especially large increases in computer investments in the last decade. Finance and insurance, business services, health services, and legal services have had especially large proportional increases in computer investments, as measured by the increase in computers' share of the total capital stock in those industries during the 1980s.

Differences between measured productivity gains and observed compensation gains in these industries are striking. In finance and insurance, where computers have been essential in creating new tools to move capital quickly, BEA's measure shows productivity growth over the period 1964 to 1986 to have been 12 percentage points below the average for all industries. At the same time, real compensation per worker in finance and insurance (deflated by the overall GDP deflator) has grown 12 percentage points faster than the average.

In the business services sector, which depends heavily on computers, productivity growth is measured to have risen 28 percentage points less than the average for all industries. Compensation also has not kept pace with the average, but growth in compensation has not been as weak, rising 18 percentage points less than the average. Health care and legal industries show the largest deviations, with measured productivity gains of 47 and 74 percentage points, respectively, *below* the average for all industries, while compensation gains were 37 and 69 percentage points, respectively, *above* the average.

This evidence is consistent with Krueger's findings. The industries that reported the strongest increases in computers as a share of the total capital stock also reported rapid growth in average compensation. If compensation is related to actual, as opposed to measured, productivity, then part of the explanation for low returns to computerization simply may be poor measurement of output from computer-using industries.

Conclusions

Data on compensation, particularly on the willingness of employers to pay for computer skills, suggest that our current statistics are undermeasuring the output effects resulting from the application of computing power in many industries. In large part because of difficulties associated with quantifying the outputs of these sectors (and adjusting for quality and timeliness), productivity growth tied to computers may be significantly understated.

The implications of these findings are significant. If the compensation data are reflecting unmeasured output growth, total output growth in the economy may be understated. Moreover, much of the hand-wringing associated with analyses pointing to the shift to a service economy may be misplaced, if the productivity gains in these growing service industries are actually much higher than current measures suggest.

Ronald H. Schmidt
Senior Economist

References

Krueger, Alan B. 1993. "How Computers Have Changed the Wage Structure: Evidence from Microdata, 1984–89." *Quarterly Journal of Economics* (February) pp. 33–60.

Loveman, Gary W. 1990. *An Assessment of the Productivity Impact of Information Technologies.* Working Paper 90s: 88-054 (September). MIT Sloan School of Management.

Morrison, Catherine J., and Ernst R. Berndt. 1991. *Assessing the Productivity of Information Technology Equipment in U.S. Manufacturing Industries.* NBER Working Paper No. 3582 (January).

Research Department
Federal Reserve
Bank of
San Francisco

P.O. Box 7702
San Francisco, CA 94120

Index to Recent Issues of *FRBSF Weekly Letter*

DATE	NUMBER	TITLE	AUTHOR
11/20	92-41	A Note of Caution on Early Bank Closure	Levonian
11/27	92-42	Where's the Recovery?	Cromwell/Trenholme
12/4	92-43	Diamonds and Water: A Paradox Revisited	Schmidt
12/11	92-44	Sluggish Money Growth: Japan's Recent Experience	Moreno/Kim
12/25	92-45	Labor Market Structure and Monetary Policy	Huh
1/1	93-01	An Alternative Strategy for Monetary Policy	Motley/Judd
1/8	93-02	The Recession, the Recovery, and the Productivity Slowdown	Cogley
1/22	93-03	U.S. Banking Turnaround	Zimmerman
1/29	93-04	Competitive Forces and Profit Persistence in Banking	Levonian
2/5	93-05	The Sources of the Growth Slowdown	Motley
2/12	93-06	GDP Fluctuations: Permanent or Temporary?	Moreno
2/19	93-07	The Twelfth District Agricultural Outlook	Dean
2/26	93-08	Saving-Investment Linkages in the Pacific Basin	Kim
3/5	93-09	A Single Market for Europe?	Glick/Hutchison
3/12	93-10	Risks in the Swaps Market	Laderman
3/19	93-11	On the Changing Composition of Bank Portfolios	Neuberger
3/26	93-12	Interest Rate Spreads as Indicators for Monetary Policy	Huh
4/2	93-13	The Lonesome Twin	Throop
4/9	93-14	Why Has Employment Grown So Slowly?	Trehan
4/16	93-15	Interpreting the Term Structure of Interest Rates	Cogley
4/23	93-16	California Banking Problems	Zimmerman
4/30	93-17	Is Banking on the Brink? Another Look	Levonian
5/7	93-18	European Exchange Rate Credibility before the Fall	Rose

The *FRBSF Weekly Letter* appears on an abbreviated schedule in June, July, August, and December.